Using Entropy to examine the mixed region between the Troposphere and the Stratosphere

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1. Abstract

The troposphere and the stratosphere each have distinct chemical signatures of ozone and water vapour. It is possible to measure the extent of mixing by examining how these signatures have merged. Using tracer-tracer relationships between ozone and water vapour, a weighting is placed on different mixed states, which are then used to calculate the entropy (a measure of mixing in the system). This method quantifies the location and size of the chemically mixed region at the boundary between the stratosphere and troposphere.

This study uses low vertical resolution global data from the Atmospheric Infrared Sounder (AIRS) on the AURA satellite. Entropy provides a method for investigating the processes by which mixing occurs. Entropy shows seasonal and short term variation along with a relationship to the location of the jet stream.

2. Data Sets

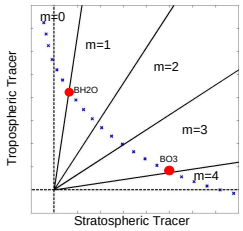
Low vertical resolution daily global data come from AIRS. Data are gridded at 1°x1° horizontal resolution, with 14 vertical levels from 1000hPa to 50hPa (approximately 2km vertical resolution), with measurements of ozone, water vapour and temperature, among a number of other parameters. AIRS ozone data is of sufficient accuracy for use in the UTLS (*Monahan et al.* 2007), as is the water vapour (*Gettelman et al.* 2004). Version 4 AIRS data is utilised in this study.

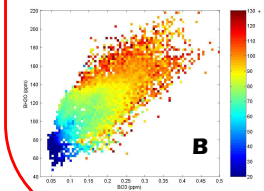
3. Calculation of Entropy and BO3/BH2O

The method for the calculation of entropy is based on *Patmore and Toumi* (2006). Two tracers, one tropospheric, H_2O, the other stratospheric, O_3, are examined in relation to each other as shown in Figure A.

The distribution is divided into weighed areas, with m=2 having the highest weighting as it is most mixed, then m=1 and 3, with m=0 and 4 having a weighting of zero. The weighted sum of the points in each region are calculated to give the entropy value. Entropy is a measure of mixing in the transition region between the troposphere and stratosphere.

A





A further parameter from tracer space of the ozone and water vapour at the boundaries can also be found, shown by BO3 and BH2O on Figure A.

Figure B shows the relationship between BH2O, BO3 and entropy (colour scale). While they are similar measures, the relationship is not compact, showing that both add information about the system. Entropy could show how mixed the profile is, whereas BO3/BH2O could show about the transport process.

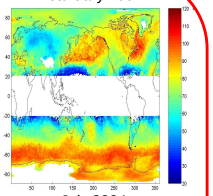
4. Uses of Entropy

Figures C and D show the mean entropy values from AIRS for January and July 2004, respectively. The blank areas are regions where entropy cannot be calculated due to limitations of the AIRS observations. A clear seasonal and hemispheric variation is seen in the entropy values. Regions of high entropy tend to be associated with the jet stream. A particularly high region is seen off the east coast of Asia during January which is associated with the East Asian Jet Stream (EAJS). Jet streams provide regions for mixing due to the large variation in the tropopause height in those regions.

In July, entropy is higher overall in the Northern Hemisphere (NH) due to the increased O3 levels during the NH summer. However there are no prominent regions as from previous studies as mixing/transport in the NH summer is low.

Patterns also vary on a daily time scale, with features able to be tracked with time. A single day of entropy data is shown in Figure H with smaller scale features.

C



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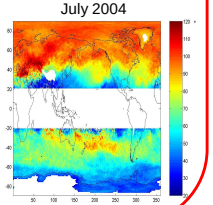
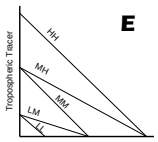


5. Thresholding based on BO3 and BH2O

The BO3 and BH2O values can be thresholded to allow for differences in the mixing lines as shown in Figure E. An 'LL' value shows that the exchange is shallow, whereas 'HH' shows that the exchange is from deep within the tracer profile.

Figure F shows the "hot spots" for each threshold, with the number of days per year that threshold is present in a grid square. We believe the higher thresholds indicate regions of deep exchange associated with jet streams and tropopause folds.

E



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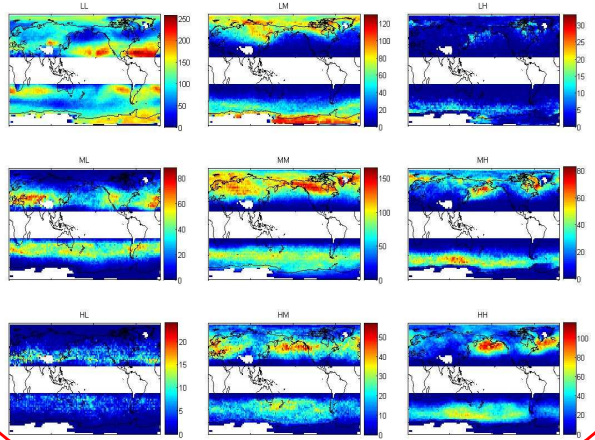
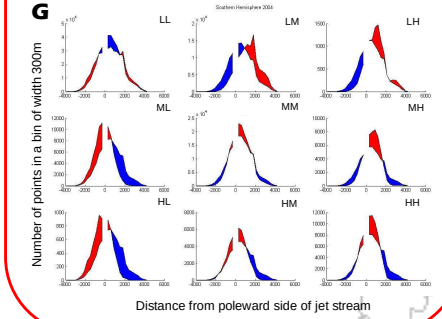


6. Distance of BO3/BH2O Thresholds from Jet Streams

The location of the jet stream is calculated from NCEP/NCAR reanalyses data at 200hPa. The distance from the jet stream to each thresholded value is calculated. If the proportion of each distance occurring was the same for each of the thresholds, a given distribution would be expected. However some distances are more likely to occur for some thresholds than others. In Figure G, regions where the distance occurs more often than expected are shaded blue, and less often shaded red. Positive x-axis values are poleward of the jet, negative values are equatorward. The gap in the centre is a result of the binning resolution.

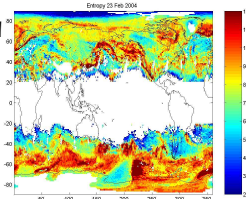
The higher threshold categories, MM MH HM HH, have more values around the jet stream, particularly on the poleward side, suggesting the jet as a transport mechanism. Also of interest is the inverted ML and HL versus LM and LH have structure which is suggestive of different transport mechanisms. Only the Southern Hemisphere is shown in Figure G, however the distributions in the Northern Hemisphere are similar.

G



7. Application of Thresholds to a Single Day of Entropy Data

H



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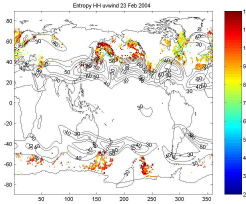

A day of entropy data are shown in Figure H, with the application of the HH threshold given in Figure I. This has highlighted interesting structures likely to be associated with the jet stream (contours on Figure I), where the transport is the greatest from the large BO3 and BH2O values. In addition, the high entropy values show the regions of large mixing.

8. Conclusions & Further Work

This poster shows entropy as a measure of mixing and the thresholding of BO3/BH2O as a measure of the magnitude or depth of the transport. We believe the combination of the two measures allows the most significant mixing to be identified. This also allows the mixing to be linked in with mechanisms.

Further work will link the "hot spots" with exchange mechanisms. A key part of this is the linkage between the distance of thresholded entropy values from the jet stream Particularly the high threshold values (MH, HM, HH) are closely related to the jet stream, which is suggestive of the mid latitude tropopause break being an important part of the exchange mechanisms.

References

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•Monahan, KP. et al., 2007, Validation of AIRS v4 ozone profiles in the UTLS using ozonesondes from Lauder, NZ and Boulder, USA. *J. Geophys. Res.*
•Patmore, N and Toumi, R., 2006, An entropy-based measure of mixing at the tropopause, *Q. J. R. Meteorol. Soc.*